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RESEARCH ARTICLE

Soil erosion rates based on anatomical changes in exposed roots – case study from southwest Bulgaria

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Abstract

In recent years different methods for soil erosion assessment have been used. Because of its high accuracy in estimations, dendrogeomorphology was selected as one suitable and reliable scientific method to achieve the main goals of this study.

The main goal of the study is to date denudation events using anatomical responses of the tree-rings of the roots. We analyze the histological changes that occur in the roots of two tree species, along the river banks of the Sedelska river, which is a tributary of Struma river.

The significant differences between homogenous groups of measurements in pre-exposed and exposed roots was established, and it shows a remarkable response of roots to sheet erosion.

Keywords

Soil erosion, dendrogeomorphology, Sedelska river

Introduction

Water erosion is a worldwide problem, which depends on many factors, but mainly on rain events and their intensity and frequency (Nicolau et al., 2022). In Bulgaria, with every passing year, in consequence of the tangible climate changes, natural hazards such as soil erosion and floods have become more and more frequent and increasingly damaging. In our country the largest number of floods occurred during the period 2005-2007 (Lubenov et al., 2009) with horrible consequences. In the following

years floods affected urban areas again with a dramatic increase in runoff (Marinov et al., 2023). Recent floods affected not only lands close to the rivers but urban territories as well, which were covered with tons of sediment like in Karlovo in 2022 and the sea side in 2023. All these natural hazards caused significant infrastructural damages and also human casualties.

For better understanding, management and in an attempt to control those processes many models for assessment the risk was used. "Methodology for preparing the national long-term programme for protecting from erosion and flooding in the forest lands" (Marinov et al., 2009) is well applied in Bulgaria for potential and actual risk of soil erosion in forest territories. For the estimation of the amount of solid runoff EPM method (Gavrilovic, 1988), IntEro (Spalevic, 2019) and USLE (Wischmeier, Smith, 1978) are used.

In recent years dendrogeomorphology has been accepted as another suitable method for erosion study. Tree rings are an excellent and frequently overlooked data source for reconstruction of chronologies of geological events (Butler, 1987). Dendrogeomorphology was successfully used for analysis of floods, debris flow and erosion processes (Silhan et al., 2016).

The article presents the results of the studies on soil erosion processes at the territory of Sedelska river by applied dendrogeomorphology in the gully side of the river.

Materials and methods

Exposed tree roots from two tree species (*Pinus nigra* Arn. and *Pinus sylvestris* L.), growing on the gully sides were used as samples during 2022-2023 (Fig. 1). We used the approach for dating of individual erosion events likely caused by some triggering hydrometeorological event. A saw was used to cut two centimeters wide cross-sections (root discs) from the exposed roots. The position of each sample was carefully recorded and the distance from soil measured.

The root discs were dried and the surface was subsequently sanded and polished. Tree-rings were measured using digital equipment for dendrochronological analysis LINTAB 5 (Fig. 2) and TSAP Win software (Rinn, 2005), with measurement accuracy of ± 0,01 mm.

Tree-rings of two radii of each root cross section were dated and measured in direction from the bark to the pit of the discs (Stokes, Smiley, 1968). One chronology was built for the normal wood, used as reference chronology (R ref) and one chronology was built for the area with reaction wood (R react), formed after root exposure (Fig. 3). Cross dating technique between measured tree rings chronologies from reference radius (R ref) and reaction radius (R react) from the same root cross section was used to define the exact year of root exposure.

The erosion rate (Er) for the position of each root was calculated as follows: ER = DR /AE, where DR is the perpendicular distance of the root sample from the soil surface, and AE is the number of years since the root exposure.

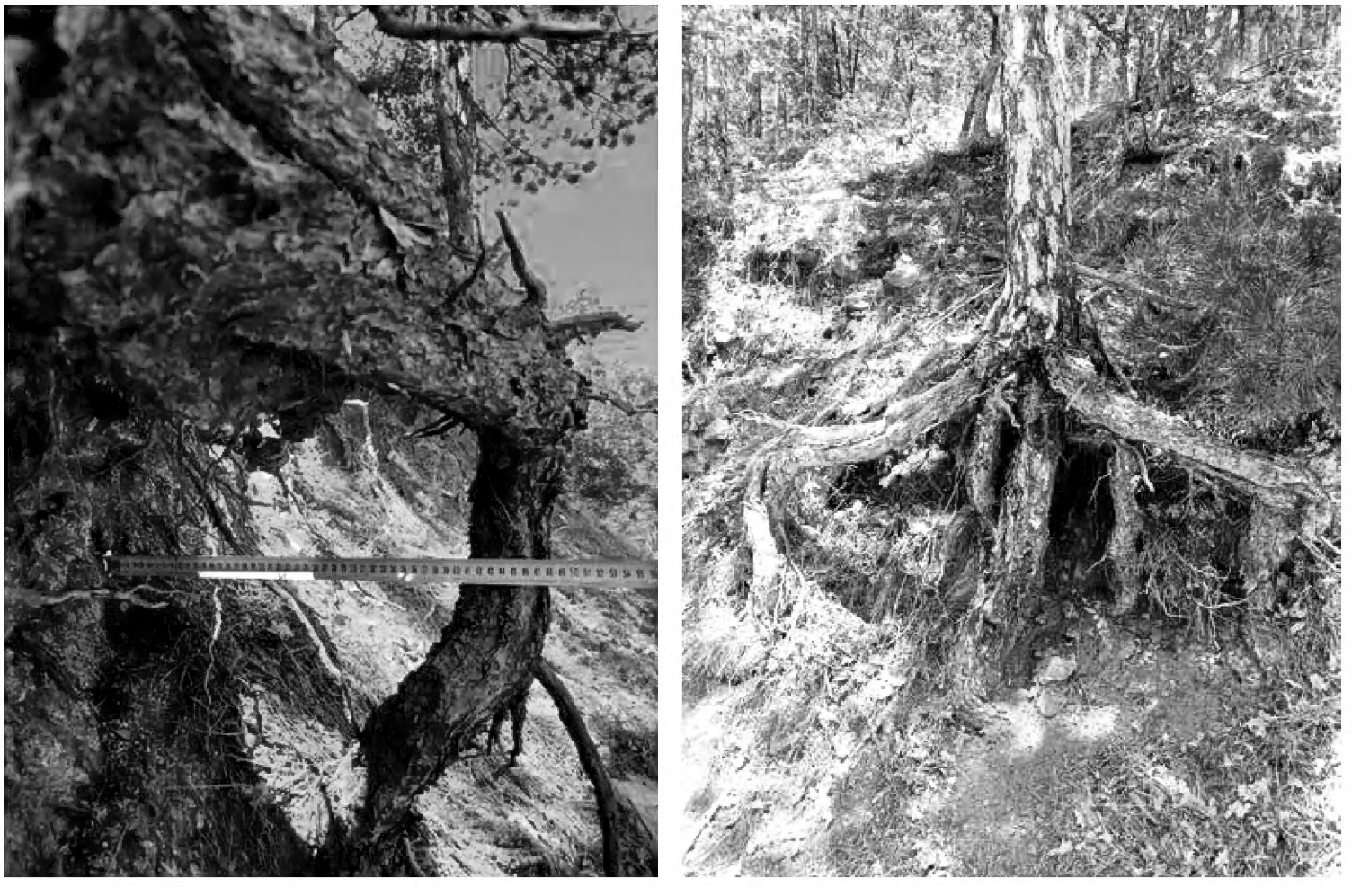

Figure 1. Morphology of eroded trees

Figure 2. LINTAB 5 tree-ring measurement equipment

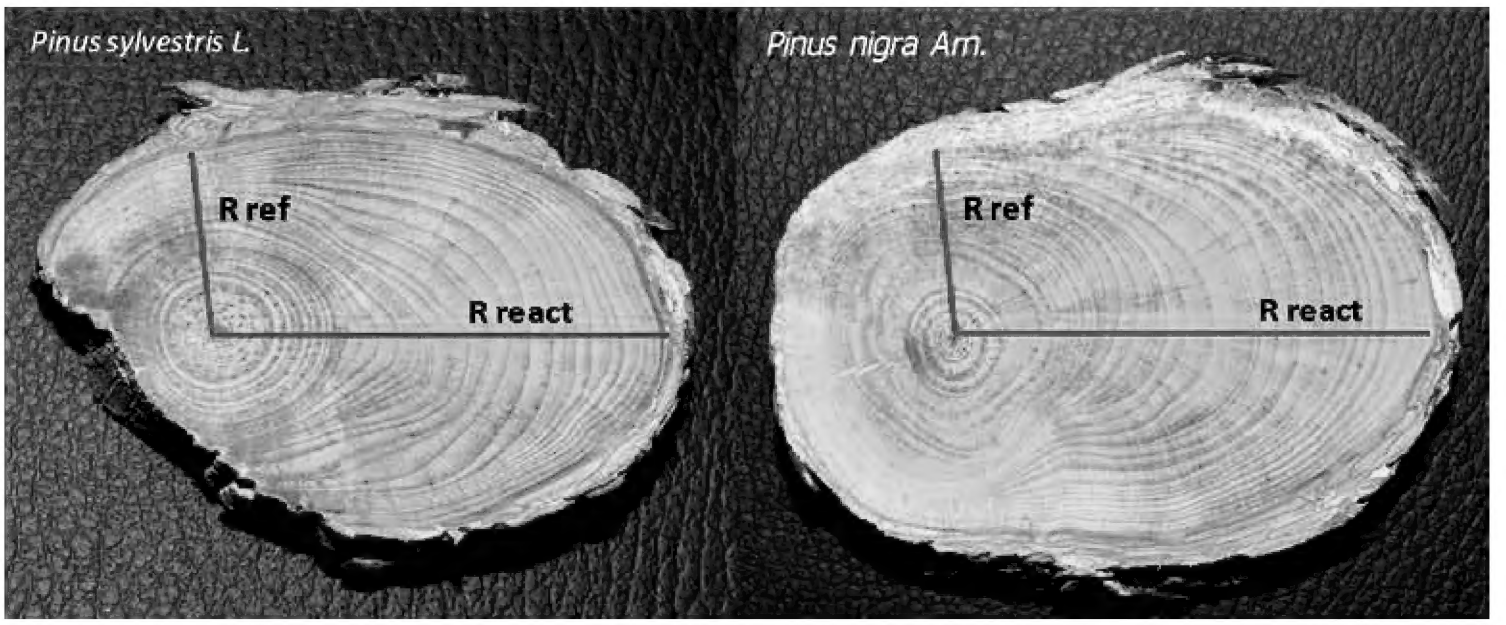

Figure. 3. Cross sections from exposed roots ready to be measured. Explanation notes: in green color (r ref) – reference tree-rings radius; in purple color (R react) – reaction wood tree-rings radius

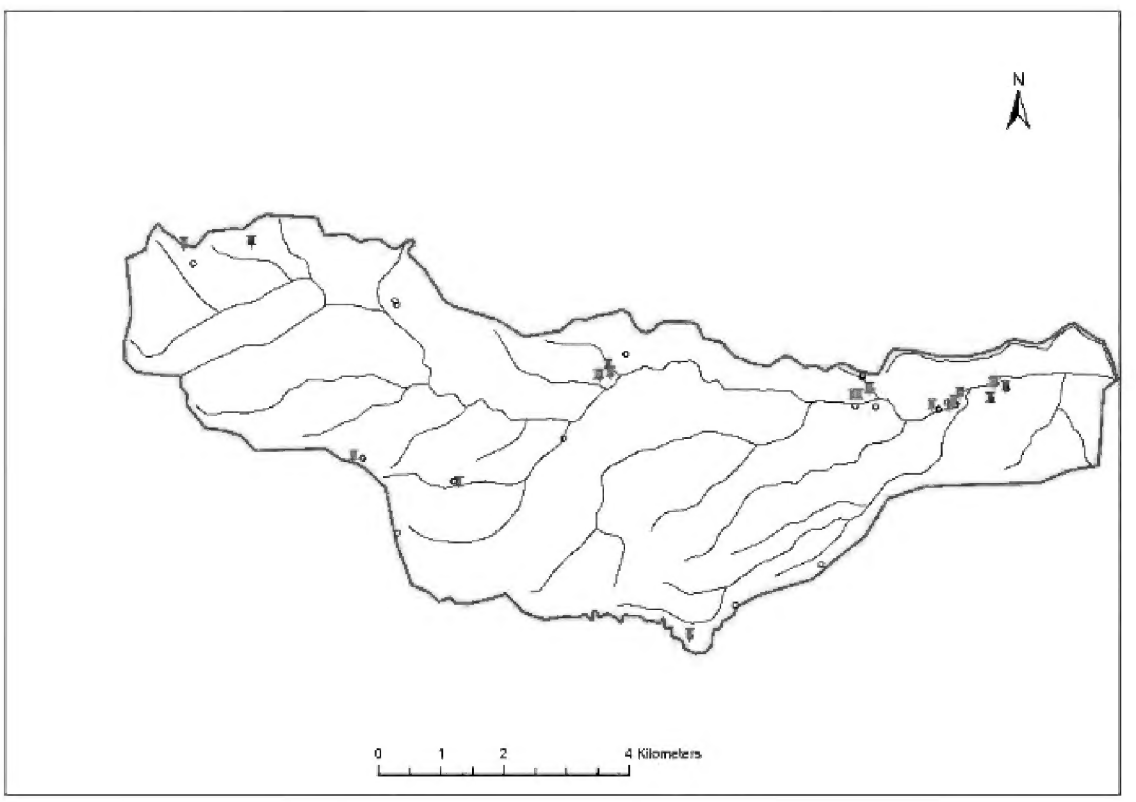

Figure 4. Watershed of Sedelska River with location of experimental trees

Results and discussion

The study area is situated in southwest Bulgaria on the watershed of Sedelska river (Fig. 4). The watershed of the river is situated on the territory of one of the most affected by soil erosion regions in Bulgaria – Regional Forestry Directorate Blagoevgrad (Marinov, Bardarov, 2005; Blinkov et al., 2013).

The total area of the watershed is 50.2 km^2, from this area 42.81 km^2 are forest territories (Pavlova-Traykova, 2022). The watershed is characterized by steep slopes,

the average slope being 20°. The soils are mainly cinnamon forest soils, but, to a lesser extent, brown forest soils are also found (Petrova et al., 2023).

Dendrogeomorphic studies usually use anatomical analysis of conifers because of a clearly visible reaction to the exposure (Lopes et al., 2011; Silhan et al., 2016). In this research 30 trees were cored for dendrogeomorphological analysis. Coniferous tree species (*Pinus nigra* Arn. and *Pinus sylvestris* L.) and broadleaves tree species (*Platanus orientalis* L. and *Quercus frainetto* Ten.) were observed. For them the results for eight coniferous trees are chosen as representative and are presented in the research.

From the observed results it was established that all representative samples from Black pine were exposed in 1999, and those from Scotch pine – in 1993 (Fig. 5).

The reason for this is probably the weather events that happened in 1993 and 1999. When looking at the data from the climate station Igralishte (Table 1), it was

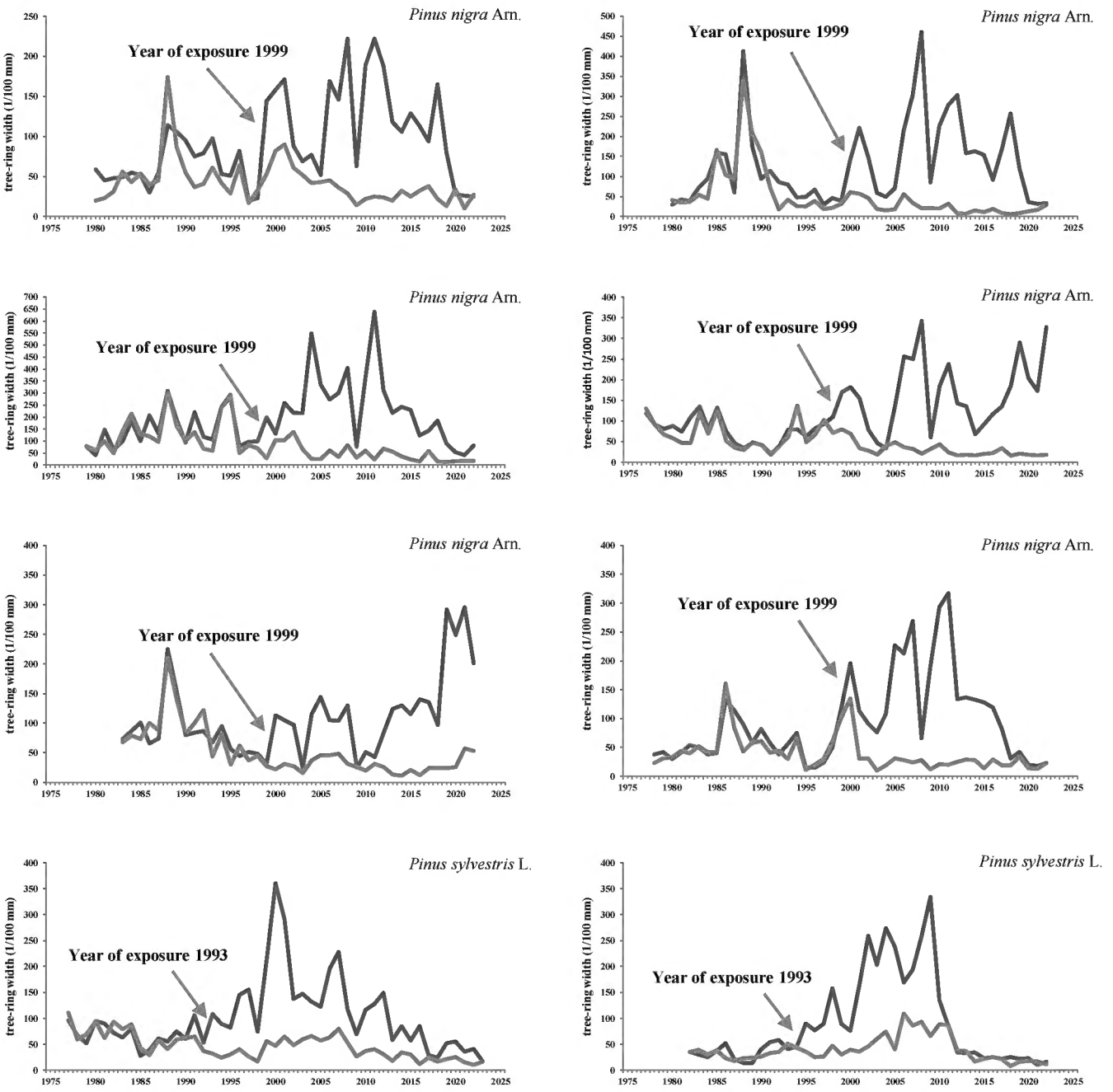

Figure 5. Examples of root exposure dating of *Pinus nigra* Arn. and *Pinus sylvestris* L. based on root tree-ring chronologies. Explanation notes: in green color – reference tree ring chronology; in purple color – reaction wood chronology from the same root

found that precisely in 1999, on the territory of the watershed, there was significant rainfall for three days in July, which has probably caused the exposure of the roots. No visible cause was noted in the rainfall study for 1993, suggesting that the cause is most likely not in climatic events.

Table 1. Heavy rains in 1999 on the territory of Sedelska river

Month	Year	Date	Characteristic of the rain			Maximum instantaneous intensity, mm/min					
			Quantity – Q, mm	Duration – t, min.	Moderate intensity – Icp, mm/min	I_5	I_{10}	I_{15}	I_{20}	I_{25}	I_{30}
		1	2	3	4	5	6	7	8	9	10
4	1999	24.4.1999	1.8	405	0.004444	1	1	0.93	0.85	0.8	0.77
7	1999	27.7.1999	28	195	0.14359	0.82	0.81	0.67	0.6	0.56	0.52
7	1999	29.7.1999	33.6	335	0.100299	0.5	0.45	0.43	0.39	0.37	0.36
7	1999	30.7.1999	35.9	245	0.146531	1.9	1.3	1.03	0.87	0.78	0.69
10	1999	22.10.1999	29	335	0.086567	0.6	0.55	0.47	0.41	0.36	0.34

The rate of soil erosion was calculated as 0.26 cm/year, which corresponded with average levels of erosion in other countries (Bodoque et al., 2011). This erosion rate is considered as low, but they are typical for hilly slope environments (Bahrami et al., 2011).

Conclusion

The method of dendrochronology proves to be a reliable scientific tool in order to identify the exact year of root exposure of the coniferous trees as a consequence of heavy soil erosion process.

Considering the information of heavy rains on the territory of the watershed it could be concluded that individual erosion event in 1999 is the reason for exposures of roots.

The reconstructed erosion rates are 0.26 cm/year which is typical for hilly slope environments like in the watershed of Sedelska river.

Additional research on other types of tree species could be conducted for more data and better understanding of the influence of soil erosion on different tree species.

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